Dynamic systems

Annie Luciani

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Annie Luciani , ACROE-ICA

Dynamic systems relate whether to a real system exhibiting some types of complex temporal behaviours whether a type of models to represent such behaviours.

There are two main types of models to represent behaviours evolving along time: models that describe the evolution of the variables representing a system explicitly along time and models in which time is an implicit variable such as those represented by set of differential equations. A simple example is in mechanics, in which the second type of model relates to the dynamics although the first one relates to the kinematics. Modelling evolutions along time through a dynamic system shifts the modelling method from an explicit description in time of these evolutions to the design of a system that is able to produce them. So doing, the system plays the role of the "invariant", able to produce the expected behaviours and revealed by all the temporal changes (possible and actual) in the exhibited behaviours.

All the real physical systems or real mock-ups can be considered as dynamic systems. However, even though that, one does not speak of dynamics systems as long as their behaviours can be represented by sets of linear differential equations, or in other words their evolutions are predictable and reversible in time. There are several types of dynamic systems. One speaks preferably on dynamic systems while at minimum two types of complexity appears in the behaviours:

1) when there are not only temporal evolution within a state (that could be represented by linear dynamics) but also there are state changing – one speak here on non-linear systems;

2) when the evolutions (with in the states and between states) are so non predictable – typical examples are systems of which the behaviour is sensitive to the initial conditions (as the well-known butterfly effect).

Examples of state changing and non-linearities are: the change of phases in critical point such as in solid-fluid-gas phase diagram, limit cycles, hysteresis, etc. Another types of dynamic systems are systems in which a process of regulation or auto-regulation maintains homeostasis against environment and conditions changes. A common feature of all the types of dynamic systems is that the behaviour of a dynamic system cannot be represented by independent (or linearly composed) components as it is possible to do in linear analysis of linear systems. When components are distinguishable, then their behaviours cannot be separated and co-evolve mutually. This leads to the apparition of emergent behaviours, i.e. to behaviours that cannot be obtain by any superposition of the behaviours of the components.

When observing complex real phenomena exhibiting such types of evolution, the characterization of the real system that produce these behaviours necessitates to take into account not only (1) the evolutions within each state, but also (2) the state-changing and (3) the types of these state-changing (for example, if it is a triple-point changing phase such as in solid or an hysteresis cycle). This means that all these changes are necessary to reveal the properties of the invariant system behind them. Vice-versa, these complex evolving behaviours cannot be modelled differently than the use of dynamic systems.

In enactive interfaces, dynamic systems and models of dynamic systems are implicated on the human side as a way to see and to model living organisms and/or their cognitive functioning, and on side of environment in which humans are interacting as a way to model and simulate dynamic objects behaviours on digital and interactive simulations.

In considering or modelling living organisms, René Thom [Thom, 1989] introduced his morphogenesis and catastrophe theories based on dynamic non linear systems. He developed methodology and models to represent non-linear state changing and he proposes a typology of state changing (fold catastrophe, cusp catastrophe, umbilic catastrophes, pitchfork bifurcation, etc.) that can be used in biology as well in sociology.

In cognitive science, the dynamic systems approaches for cognition assume that cognition may be modelled by – and thus understood as – as a dynamic system. The key example given in [van Gelder, 1998] is that of the "Watt's centrifugal governor". The Watt's centrifugal governor is a mechanical system, designed by James Watt in the late of 18th century to regulate at a constant value the speed of a steam engine. The regulator controls automatically the aperture of a throttle valve that consequently regulates the amount of the steam flow entering into the boiler. What it is interesting is not what the Watt governor does, but how it does it. Instead of implementing such regulation by decomposing the regulation elements into components, the governor achieves the same aim through a mechanism that implements implicitly such a function leading to a complex regulated behaviour. In Watt's governor, the task is performed without any explicit representation of the evolution of the system and of its states. It is typically a dynamic auto regulated system.

In materialized models of living and human behaviours, as those developed in autonomous robotics or in artificial life (as approach like [Beer, 1995], the aim is to design autonomous robots able to walk without any explicit description of the walking. Dynamic models are used of several types: physically-inspired models, neural-network inspired models etc. The most famous representatives of that approach are the Brooks' creatures [Brooks, 1991a] [Brooks, 1991b].

In simulation of physical worlds with which humans interact, as used in virtual reality systems, robotics implementation of haptic control refers to dynamic systems framework. Morever, the instrumental approach developed by Cadoz, Luciani, Florens and co-workers [Luciani, 2004] [Tache et al., 2006] [Chanclou et al., 1994] necessitates to have at disposal models of the real world and simulation for the virtual objects and worlds that are based on dynamic systems. They assume that it is very fruitful an efficient paradigm to reconstruct genuine multisensory interaction between humans and virtual worlds. They assume that the system human-object and further human-virtual object through multisensory interactions (and mainly through force feedback interaction) has to be considered as a dynamic system and that the dynamics of the coupling is a major element to instantiate enactive interaction and to convey properties such as embodiment and emergent behaviours in a context of digital instruments.

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